

PACIFICONSM 2022

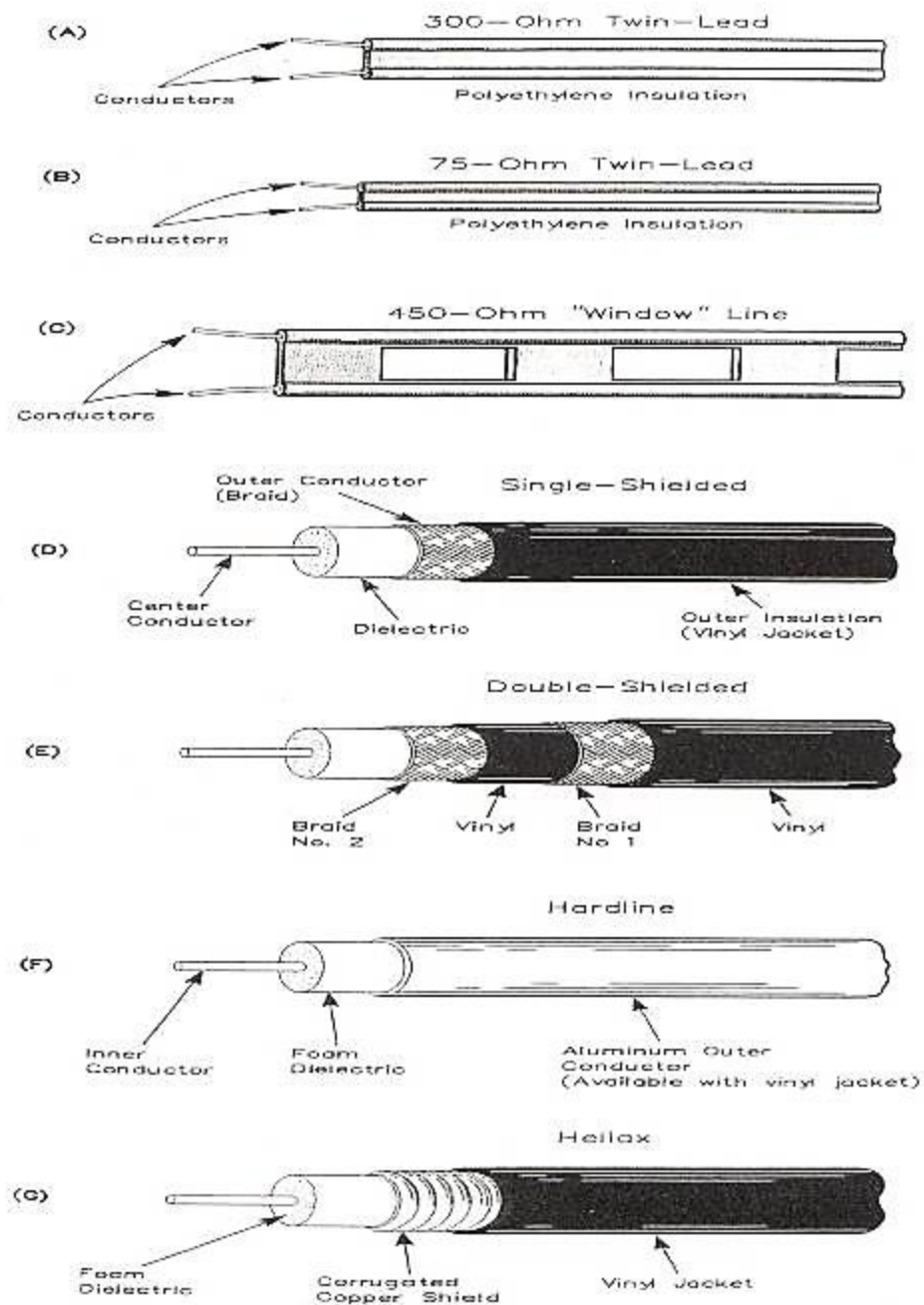
ARRL Pacific Division Ham Radio Convention
Produced by the Mount Diablo Amateur Radio Club



Every Connection Counts: Coaxial Cable



An Interconnection system of Radio Frequency (RF) cables and connectors



Application Specific Requirements

- In this webinar we cover Radio Frequency properties of interconnecting cables and connectors and the effect of electrical, mechanical, and environmental conditions on them. Entire specifications, standards, and handbooks have been written on this topic.

Such as:

- Mil-C-17 General Specification for Radio-Frequency, Flexible, and semi rigid cables
- IEC 60096-0-1:2012 Guide to the design of detail specifications - Coaxial cables
- SAE ARP 1705 Coaxial Test for measuring RF shielding properties (Transfer Impedance).

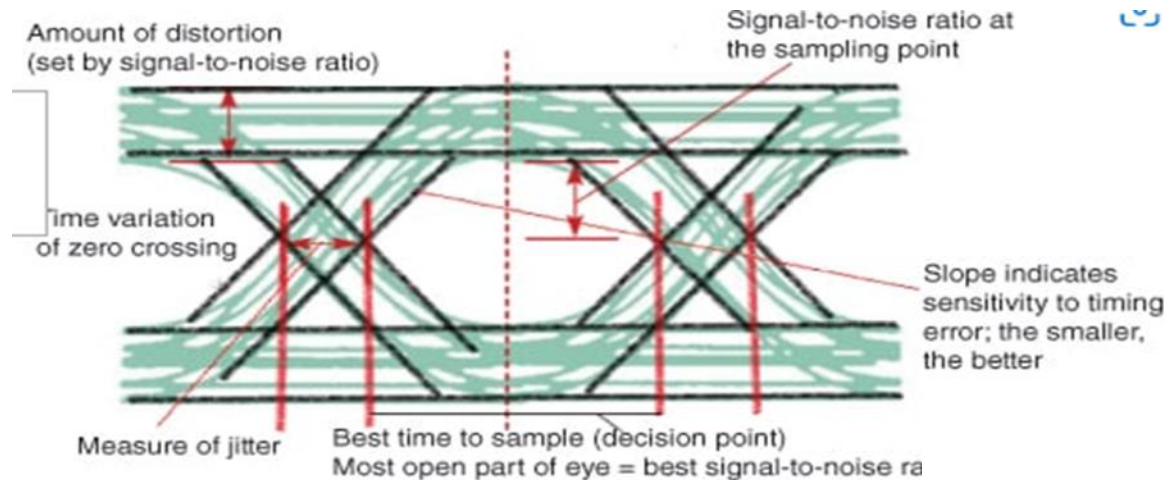
Traveling Waves

Analog and Digital Signals

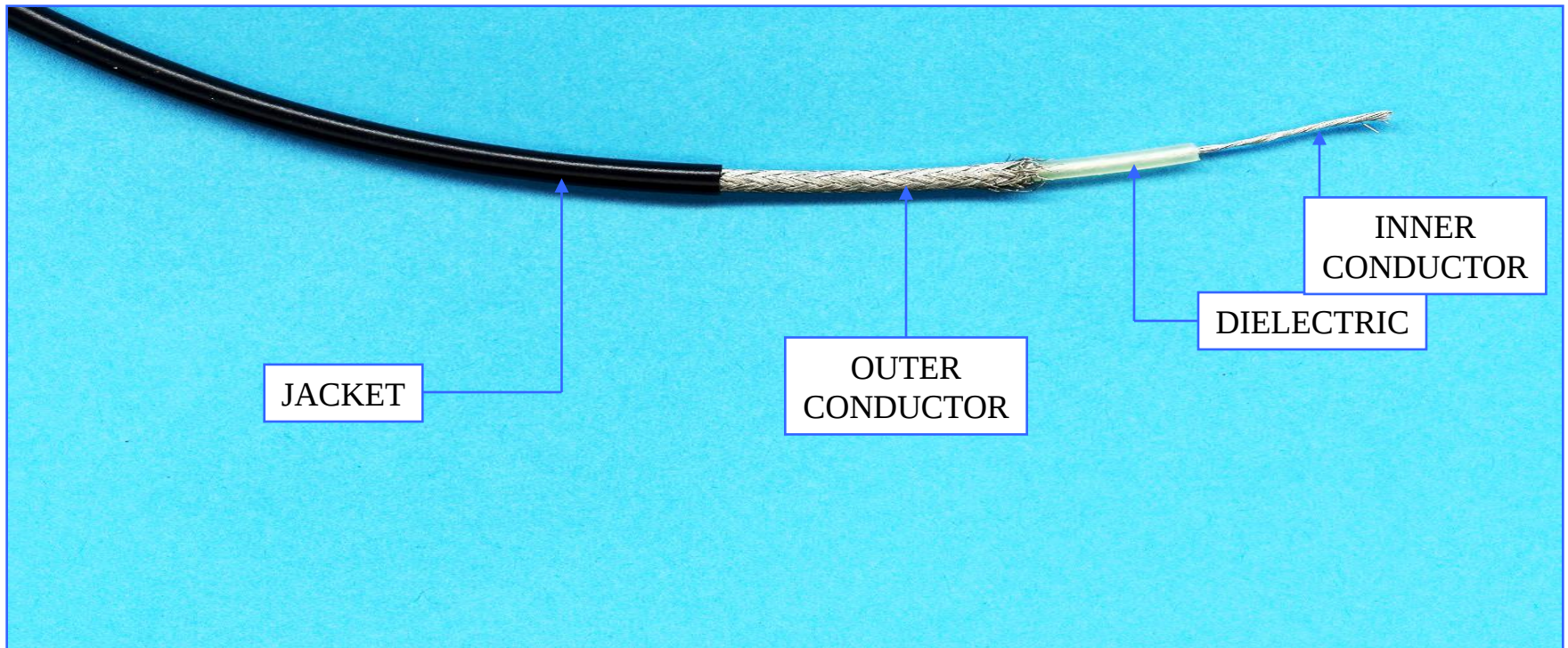
Analog



Digital



FLEXIBLE RADIO FREQUENCY CABLE (COAXIAL) M17/28-RG058

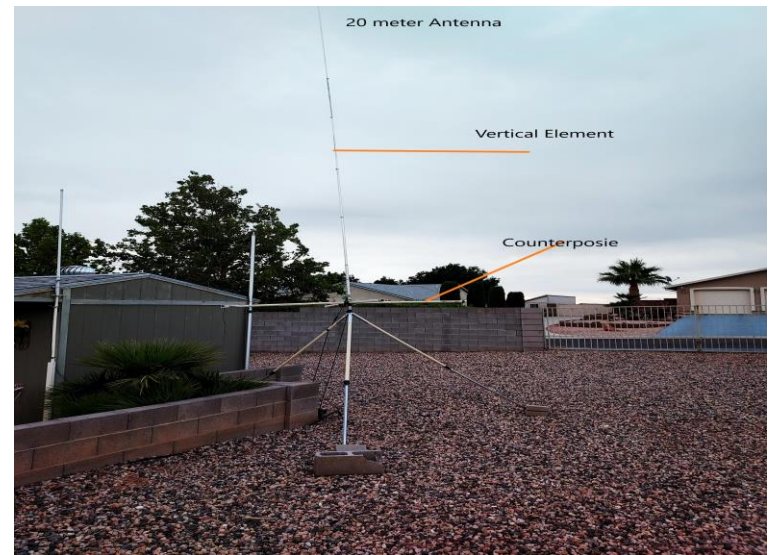
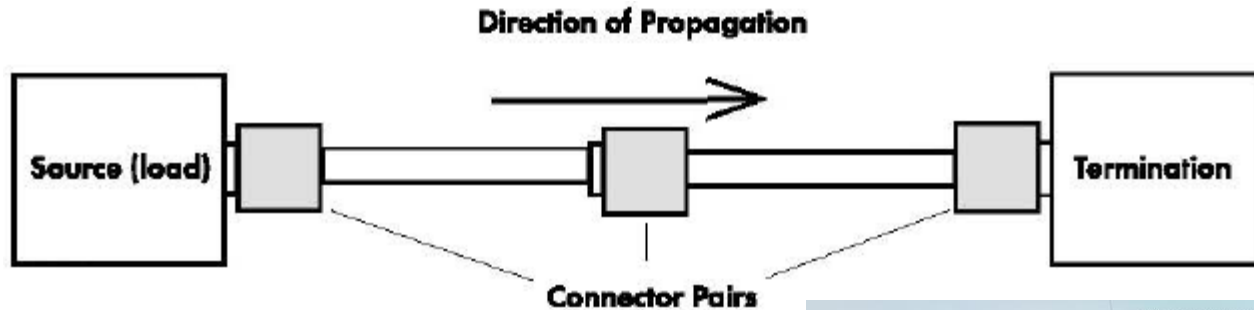


RG58 is general purpose.

What other RG cable do you use.

How do they compare

COMPONENTS OF AN INTERCONNECTION SYSTEM



How many other applications can you imagine for this white transmission line?

CABLE PROPERTIES-ELECTRICAL PERFORMANCE

TRANVERSE ELECTROMAGNETIC WAVES (TEM) - TRAVELING WAVES

- PROPAGATION CONSTANT - VELOCITY OF PROPAGATION (V_p)
- DIELECTRIC LOSS - DIELECTRIC CONSTANT (ϵ)
- CHARACTERISTIC IMPEDANCE (Z_0)
- HIGH FREQUENCY LOSS - ATTENUATION (dB)

STANDING WAVES (VSWR)

EMI

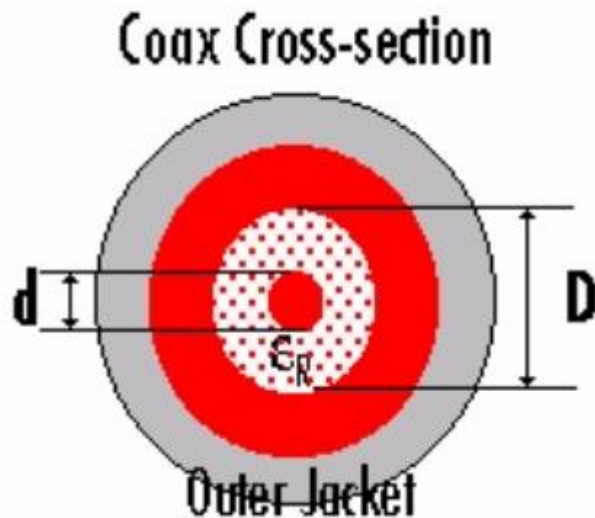
- SHIELDING THEORY
- BRAIDED SHIELD
 - ✓ CARRIERS
 - ✓ PICKS
 - ✓ BRAID ANGLES

HAZARDS AND ENVIRONMENT

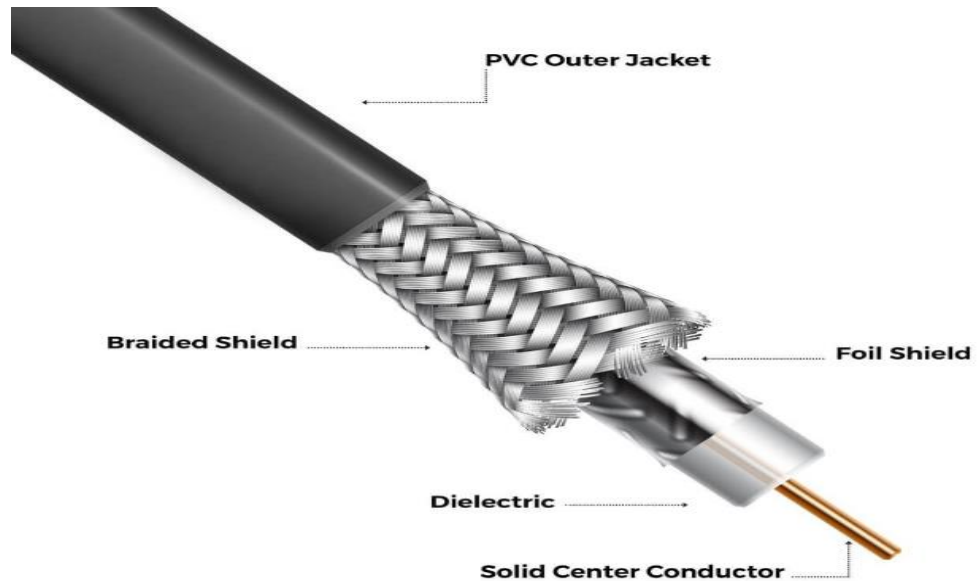
- COVERS
- TEMPERATURE
- FLUIDS
- ALTITUDE

A Fundamental Coax Cable Consists of 4 Main Components

- Inner Conductor
- Outer Conductor
- Dielectric
- Jacket



LMR Cable – The next generation



Next generation double shielded cables can be used
with N6BT next generation antennas

Coax Shield Braid Comparison



LMR 400



RG 58



Messi & Paoloni
UltraFlex 10/.400

Which one do you choose? Why?

Application Specific

Application:

Rig: Elecraft K3 (100 watt transceiver)

Amplifier: Ameritron 811 (600 watt output)

Tuner: MFJ 962D

Selected Cable: ????

Selected Connector: ???

- Should you be concerned about cable selection?
- Does the connector meet the frequency, shielding, and interlocking coupling needs for this application?

Propagation Constant (Velocity of Propagation)

- If the dielectric (insulation) between the inner and outer conductors is a vacuum the traveling (Electromagnetic) waves propagate through a transmission lines at 186,000 miles per second (300,000,000 meters per second) if the dielectric (insulation) between the inner and outer conductor is vacuum.
- A dielectric material placed between the inner and outer conductors reduces the speed of the electromagnetic wave referred to as the Velocity of Propagation (V_p).
- Every insulation material except air reduces wavelength
- Every insulation material except air reduces velocity of propagation
- Both effects increase with dielectric constant

Substances and their Dielectric Constants

Substance	Dielectric Constant
Vacuum	1
Air	1.00054
Glass	5-10
Nylon	3.5
Polyethylene	2.3
Polystyrene	2.6
Rubber	2-3
Teflon	2.1
Water (20°C)	80

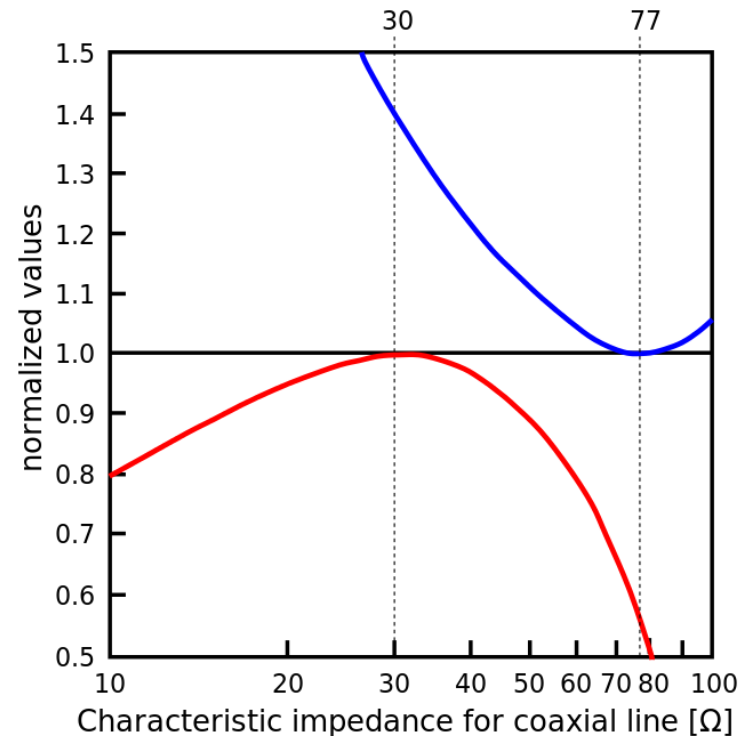
- As an electromagnetic wave travels down the transmission line the inner and outer conductors exhibit a characteristic inductance and capacitance know as the Characteristic Impedance (Z_o).
- This characteristic impedance is calculated using the following formula:

$$Z_o = \frac{138 \log_{10} \left(\frac{D_d}{D_c} \right)}{\sqrt{\epsilon_R}}$$

where D is the inside diameter of the outer conductor, where d is the outside diameter of the inner conductor when $\frac{D}{d} = 2.3$

Typically
 $Z_o = 49.9 \text{ Ohms}$

Why is 50 ohms gold standard



Attenuation (blue) is lowest at 77 Ω (for $\epsilon_r = 1$)

Maximum power capacity (red) peaks at 30 Ω

PL259 Zo and SWR

PL 259 Plug 259

SO 239 Socket 239

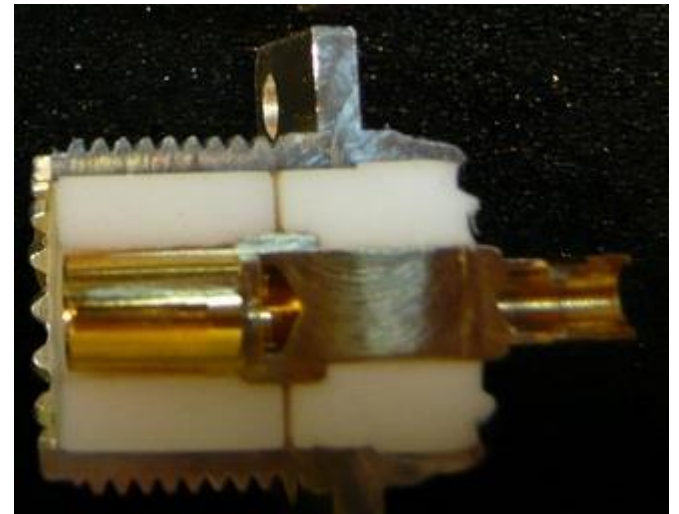
Dims: Outer dia of pin .155

Inner dia of outer shell .478

$Z_o = 138 \log (O_d/I_d)$

$Z_o = 67.4 \text{ ohms}$

$SWR = Z_l/Z_o$



Propagation Constant (Attenuation)

- As the electromagnetic wave continues traveling down the transmission line any amount of attenuation or power loss will occur. This loss is dependent on the dielectric for insulating conductors, power escaping due to radiated emissions, and mismatched loads (receivers).
- Attenuation is measured in decibels (dB).

Coax Cable Attenuation

Attenuation (dB per 100 feet)

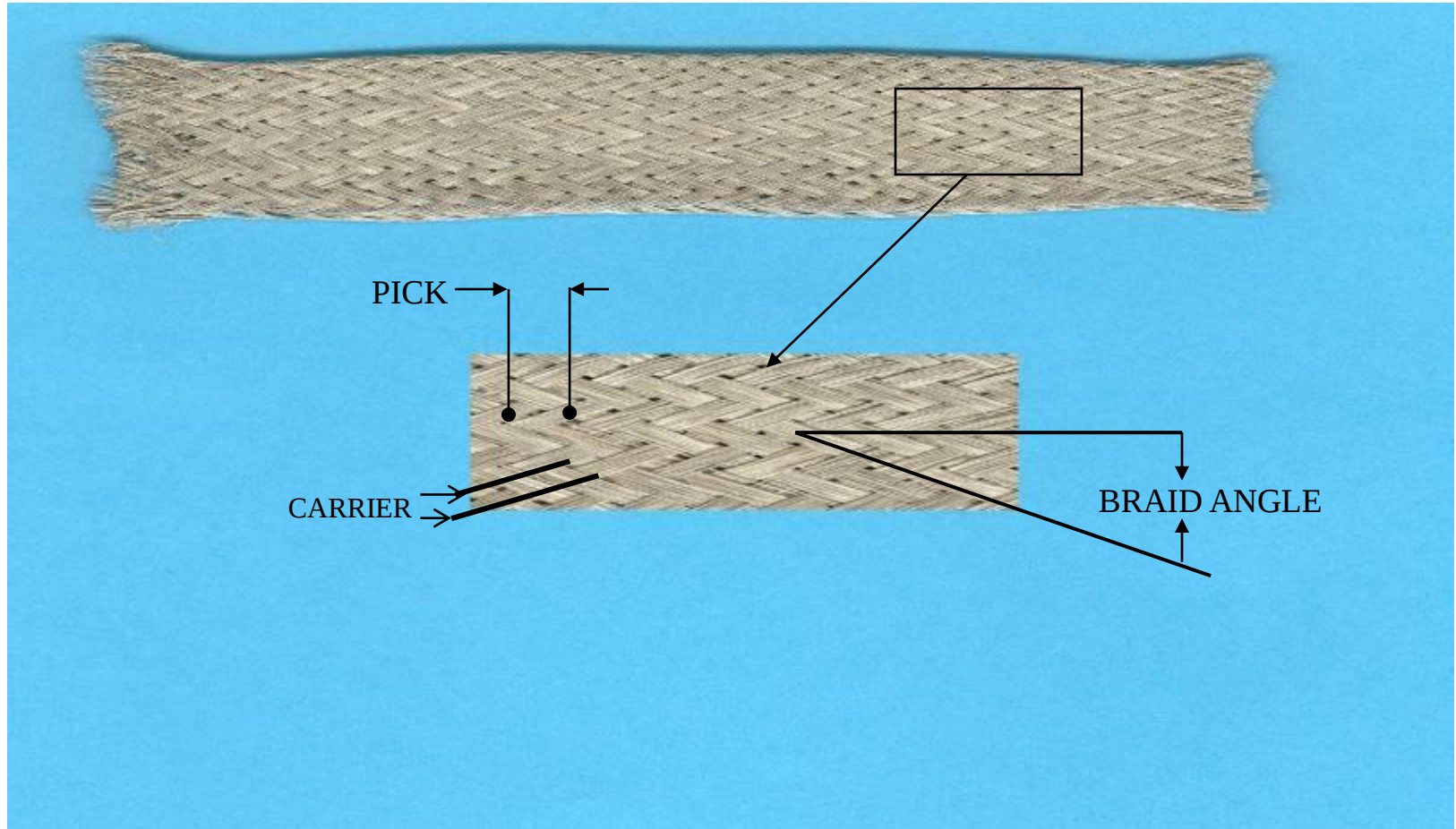
Coax Cable Signal Loss (Attenuation) in dB per 100ft*

Loss*	RG-174	RG-58	RG-8X	RG-213	RG-6	RG-11	RF-9914	RF-9913
1MHz	1.9dB	0.4dB	0.5dB	0.2dB	0.2dB	0.2dB	0.3dB	0.2dB
10MHz	3.3dB	1.4dB	1.0dB	0.6dB	0.6dB	0.4dB	0.5dB	0.4dB
50MHz	6.6dB	3.3dB	2.5dB	1.6dB	1.4dB	1.0dB	1.1dB	0.9dB
100MHz	8.9dB	4.9dB	3.6dB	2.2dB	2.0dB	1.6dB	1.5dB	1.4dB
200MHz	11.9dB	7.3dB	5.4dB	3.3dB	2.8dB	2.3dB	2.0dB	1.8dB
400MHz	17.3 B	11.2dB	7.9dB	4.8dB	4.3dB	3.5dB	2.9dB	2.6dB

- If the transmission line characteristic impedance (Z_0) does not match the source (sending) or the load (receiving) impedance a mismatch occurs resulting in a reflection of the emission signal. From the receiving to sending unit the ratio of the signal transmitted to that reflected is a Reflection Coefficient (ρ) or Standing Wave Ratio (SWR).
- An SWR should ideally be less than 2:1 and no greater than 3:1
- An SWR greater than 3:1 has potential of damaging the source electronic equipment.

- As noted earlier a loss of power can be attested to radiated emissions which in turn can cause Electromagnetic Interference (EMI).
- To prevent EMI a braid is used that completely surrounds the dielectric. The performance of the braid is dependent on a number of properties
 - ✓ Picks
 - ✓ Carriers
 - ✓ Braid Angles

WIRE BRAID (TIN COATED, TUBULAR, COPPER) QQB575R34T781 (BELDEN 8862)



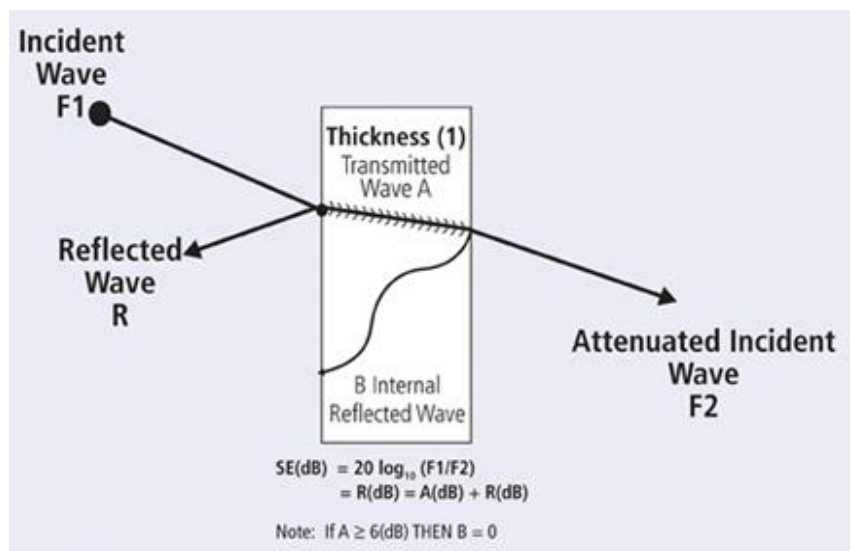
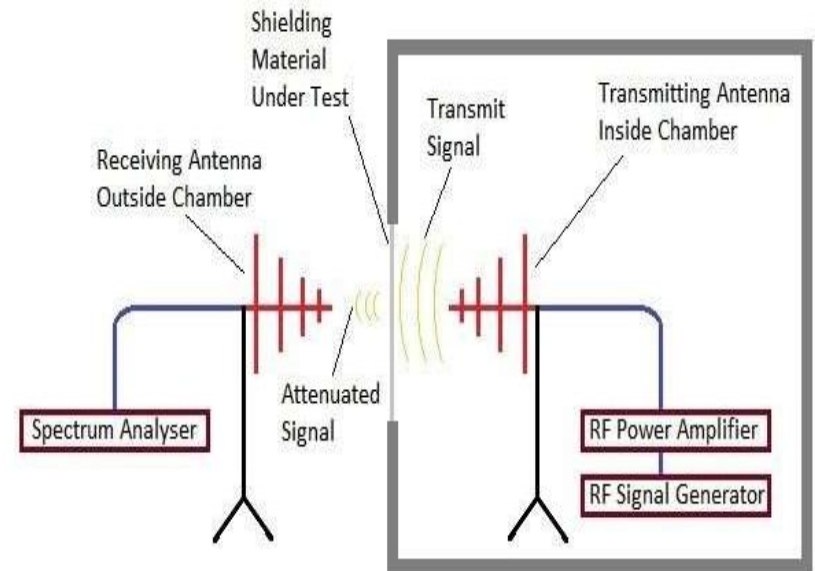
If a coaxial shield braid is not properly maintained, grounded, or if it is damaged a number of any harmful conditions can exist

- ✓ High SWR
- ✓ Equipment damage-Power Amp
- ✓ EMI leakage-Radiated Emission
- ✓ Passive Intermodulation (PIM)

WHAT EXACTLY IS EMI LEAKAGE

- It is electromagnetic energy causing undesirable responses to other equipment.

How Does A Shield Work?



Having a transmission line *without interrupts* is ideal.
However, in the real world, we require a way to
connect and disconnect a transmission line using
Coaxial Connectors

Connectors require:

- Assembly
- Maintenance
- Modification
- Inspection
- Troubleshooting

Do Radio Frequency connectors go bad?

RF connectors must be compatible to the cable.
Key requirements in choosing the correct connector are:

- Physical properties
- Electrical characteristics
- Coupling method
- Termination mode (Captivation)
- Cost

Physical properties



Electrical characteristics

- Male or Female connector
- Dimensions of the inner conductor to outer conductor
- Plating
- Frequency of application
- Power handling capability
- Impedance
- Passive Intermodulation



Coupling Mechanisms

- Threaded
- Bayonet
- Push-On



Assembly Tools & Instructions

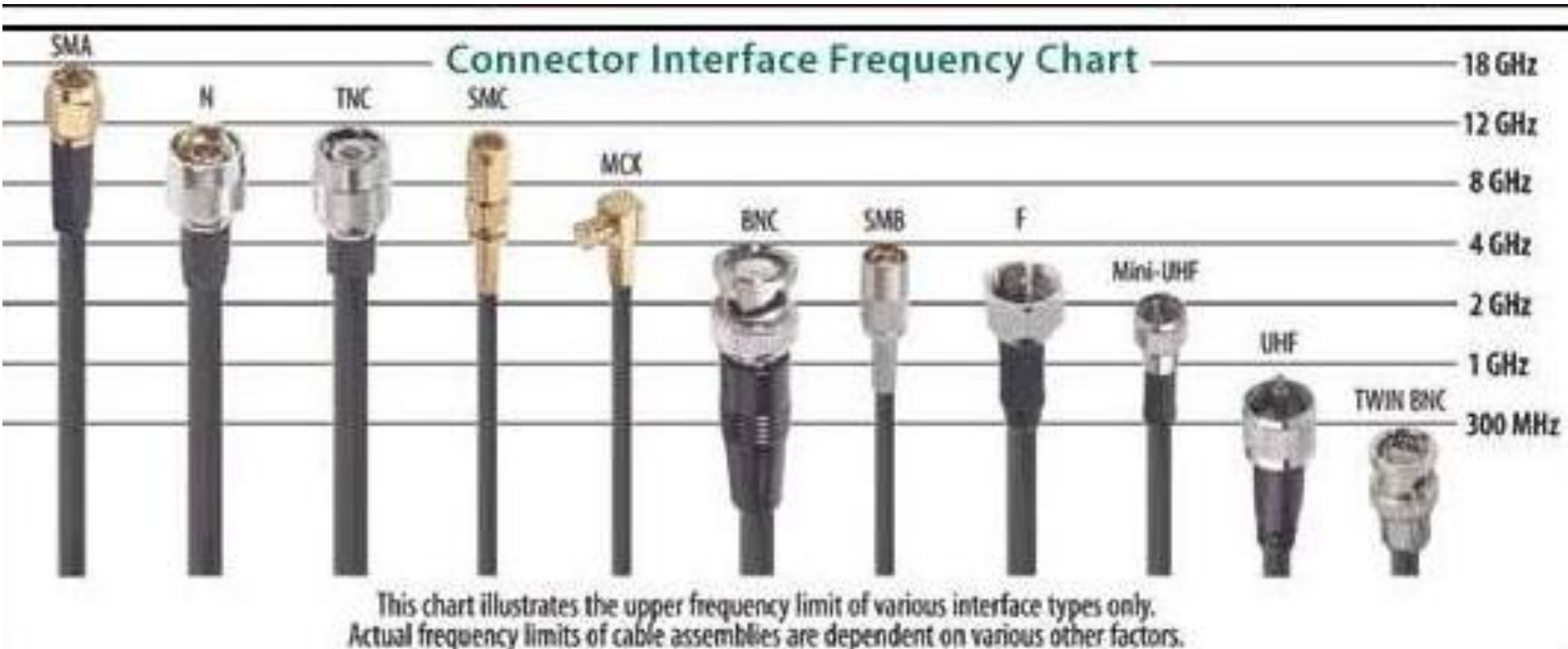
- Reliable & Repeatable Assembly
- Assembly instructions
- Cost of tooling vs incorrectly assembled components



- Solder
- Clamp
- Crimp



Connector Frequency Interface Chart



UHF (Ultra high Frequency) connectors



Type N (Navy) connector



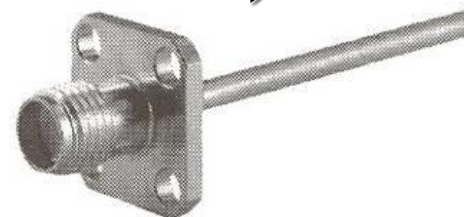
F Connectors



BNC (Bayonet Locking Neil-Concelman) connector



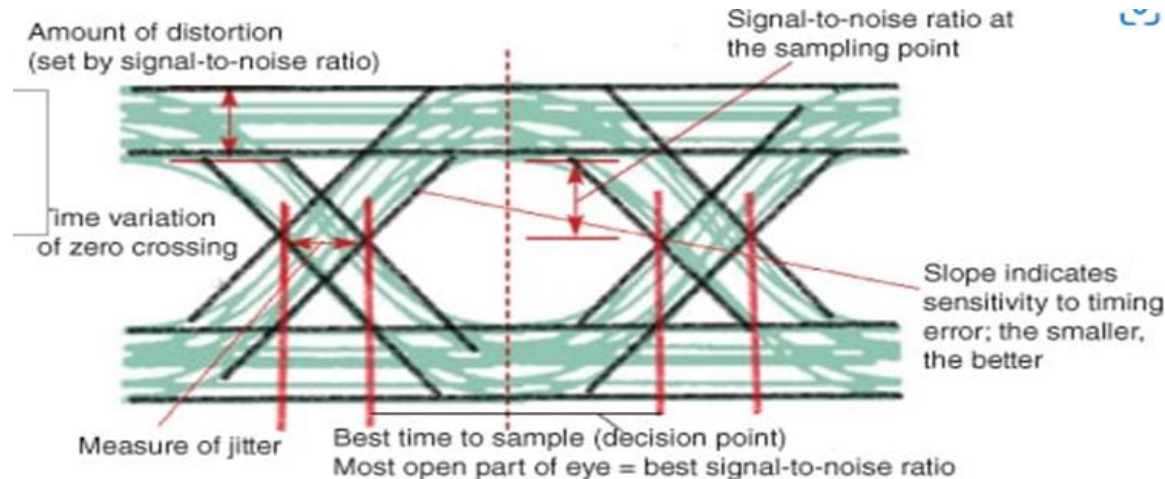
SMA (Sub-Miniature version A) connector



HDMI & USB Connectors

PC-Transceiver-Monitor Interfaces

Bandwidth Capacity 5Gbps-18Gbps



References

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- ARRL Antenna Book
- ARRL Handbook
- Reflections III Transmission Lines and Antennas, Maxwell
- High Speed Digital Design, Johnson and Graham
- Electromagnetic Compatibility Engineering, Ott
- Suhner RF Connector Guide, Huber & Suhner
- The Electromagnetic Theory of Coaxial Transmission Lines and Cylindrical Shields, Shelkunoff
- Mil-C-17, Military Specification Radio Frequency Cables
- In Compliance, August 2022
- www.Testandmeasurementtips.com , August 2016

**and...That's Everything in an
Egg Shell.....**

